TUNNELS OR BRIDGES?

The Problem of Transportation Across the East River

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TUNNELS OR BRIDGES?

BEING A COMMUNICATION

TO THE

Board of Estimate and Apportionment

FROM

Hon. BIRD S. COLER,

COMPTROLLER

OF

THE CITY OF NEW YORK

ON THE

Subject of transportation across the East River, with reports favoring and opposing the views therein set forth by

WILLIAM BARCLAY PARSONS, JACOBS & DAVIES, R. S. BUCK,
C. C. MARTIN AND SAMUEL R. PROBASCO

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CITY OF NEW YORK—DEPARTMENT OF FINANCE,
OFFICE OF THE COMPTROLLER,
December 4, 1899.

To the Board of Estimate and Apportionment:

GENTLEMEN—On November 29, 1899, the Board of Public Improvements approved sketch plans of two bridges to be constructed across the East river, between the Borough of Manhattan and the boroughs of Brooklyn and Queens, respectively. The estimated cost of these two bridges is $28,382,100.

The Board of Estimate and Apportionment has been requested by the Department of Bridges to authorize the issue of bonds to the amount of $1,000,000 to provide for the construction of foundations for the piers. It is manifest that the expenditure of even this comparatively small initial outlay will commit the City irrevocably to the whole of the cost contemplated.

I urge the Board of Estimate and Apportionment not to take immediate action on this request for two reasons: first, because the application is premature and no real saving of time can be gained by acting thereon at this meeting; and, secondly, because I believe that a much speedier, better, more economical and more efficacious method exists for solving the problem of intercommunication between the several boroughs of the City than by the building of these bridges.

The plans approved by the Board of Public Improvements on November 29 were mere sketches showing only the height

and direction of the bridges. Their sole purpose, as explained by the Commissioner of Bridges at that meeting, was to secure the official approval of that Board on these two points, so that in turn the approval of the Secretary of War could be obtained on these preliminary features, which alone interest his Department. Until the approval of the Secretary of War is obtained it would be useless to submit detailed plans and drawings, since any change as to height or location of piers insisted on by that official might render them valueless.

Even, therefore, if the $1,000,000 requested by the Bridge Commissioner were immediately available, nothing could be done until the approval of the Secretary of War had been obtained, the detailed plans and drawings prepared by the Department of Bridges and approved by the Board of Public Improvements, and the necessary ordinance passed by the Municipal Assembly.

I have referred to these facts merely for the purpose of showing that in any event, and even if the Board of Estimate and Apportionment should ultimately disagree with the arguments I am about to present, there is absolutely nothing to be gained and no time to be saved by hasty and immediate action on the request of the Commissioner of Bridges.

My main reason in presenting this report, however, is to lay before the Board certain questions of the utmost importance, which, so far as I know, have never received the slightest consideration by any public officer, and upon the correct solution of which the future development of the city depends in greater degree than in the case of any matter ever presented to this Board for determination.

The necessity for better means of intercommunication between these boroughs is no longer a matter open to argu-

ment. It is admitted by practically every one, and has been advocated by none more strenuously than by your subscriber. It is by no means certain, however, that this problem can be solved in the most economical or efficacious manner by the building of bridges. Their cost is extremely great. If past experience be taken as a guide, the cost of these two bridges will, in all probability, largely exceed the estimate furnished by the Department of Bridges. But assuming that this estimate will not be exceeded, it is, nevertheless, proposed to enter at once into an outlay nearly as great as that required for the construction of the Rapid Transit road throughout the entire length of the Borough of Manhattan, which has now become possible, after eight years of preparation and two votes of the people, only by the adoption of an amendment to the Constitution of the State. As a matter of course, the delays incidental to the Rapid Transit problem in the boroughs of Manhattan and The Bronx constitute no reason why the bettering of transit facilities across the East river should be similarly delayed. On the contrary, this experience only admonishes the necessity for much prompter action. It would be extremely unfortunate, however, if, in the desire to expedite these improvements, the City should become committed to an enormously expensive plan which future experience should prove to be erroneous, wasteful and inefficacious.

The advantages of tunnel building over bridge building have never been officially considered by any board or department of the City Government, and the general public is, I believe, wholly uninformed as to the extent to which the former has supplanted the latter in England as a means of crossing navigable streams. Only the few who have actually traveled in the tunnels under the Thames and the Mersey realize the

enormous advantages of this means of transportation. To cite an example nearer home, however—at our doors, in fact—it will doubtless surprise most people to learn that the tunnel under the East river constructed by the East River Gas Company, is ten and a half feet in diameter, which is four inches more than that of the City and South London tunnel now in daily use for transportation purposes in the City of London. The East River Gas tunnel, besides holding the large mains of that company, contains a railroad track regularly used by freight cars. This tunnel could be duplicated to-day for considerably less than $500,000, or, say, between $800,000 and $900,000 for two such tunnels, one for east-bound and one for west-bound trains.

The Long Island Railway Company has recently made application for permission to construct, at its own expense, for general railway purposes, a tunnel under the East river. Owing to its great length, especially in the Borough of Brooklyn, a comparison cannot fairly be made between its cost and the cost of either tunnels or bridges which merely serve to connect the river-fronts of the two boroughs. Nevertheless, the cost of this tunnel throughout its entire length will only be between five and six millions of dollars. This is about one-third of the cost of one of the proposed bridges.

The comparative cost of construction, however, while extremely important, is only one of the questions to be considered. Others are as follows:

Tunnels can be constructed much quicker than bridges. In the actual work of constructing the East River Gas tunnel it was found possible to advance 100 feet per week. At this rate, working from both ends, it would be possible to construct one mile of tunnel in six months. Assuming, however, that

this high speed could not always be maintained, and making due allowances for unforeseen obstacles, it seems reasonably certain that a tunnel between Manhattan and Brooklyn or Manhattan and Queens could be ready for operation within two years from the letting of the contract. It is not likely that a bridge could be constructed in twice that time.

The physical advantages of tunnels over bridges for railroad purposes are also worthy of consideration. Railroads crossing a bridge start on a sharp up-grade which it requires a maximum of power to overcome. The contrary is true of a tunnel, where gravity alone will carry a train almost to the end of the route, and only a minimum of power is required. Furthermore, a tunnel is constructed on the firmest of foundations, while a bridge is suspended in mid-air. There is no limit, therefore, to the length, weight and number of trains that can be run on a tunnel roadbed. Trains on the Brooklyn Bridge have a speed of about ten miles an hour. Trains are run through a tunnel at from thirty to forty miles an hour. This means that fully twice as many passengers can be carried under conditions otherwise equal.

Bridges over the East river at a height of 155 or 160 feet require long approaches, for which enormously expensive pieces of private property must be acquired by purchase or by condemnation proceedings. Tunnels can be constructed wholly within the lines of city streets, and interfere scarcely at all with vested property rights.

Bridges are pieces of machinery which must be constantly watched and carefully maintained at large expense; tunnels, on the other hand, after their first cost, require scarcely any expenditure for maintenance.

The greatest advantage of tunnels over bridges, however,

is, in my judgment, yet to be stated. Tunnels can be constructed in practically any locality and can, therefore, be planned to run to and from such points as will best serve the natural tide of travel. Bridges, on the contrary, must be constructed at the arbitrary locations necessitated by the topography of the city and the configuration of the river. It is at least an open question whether the new bridge planned between the boroughs of Manhattan and Brooklyn will accommodate travel to and from the most necessary points. It will doubtless serve to relieve the pressure on the old Brooklyn Bridge, but to some extent its purposes and results will duplicate those of that structure. The needs of the most rapidly growing district in Kings County—South Brooklyn—will not be met at all. In offering these remarks it is far from my intention to criticise the action of the Bridge Department, which, I understand, could scarcely have acted otherwise than it has in the preparation of these plans; since a bridge to relieve South Brooklyn was, in view of the engineering and financial difficulties, a practical impossibility. A tunnel to the South Brooklyn district, however, is entirely feasible.

This difficulty experienced by the Bridge Department in locating a bridge where it is most needed illustrates forcibly the chief advantage of a tunnel over a bridge.

The New East River Bridge now under construction starts in Brooklyn from a moderately useful location and ends in Manhattan—nowhere. These two bridges now proposed both begin and end nowhere. Only the old Brooklyn Bridge, which occupies an exceptional position, for which no parallel can be found, connects two great natural receiving and distributing points—the two city halls.

In the case of the New East River Bridge, the Manhattan

approach of which is to terminate far east of the Bowery, can it be doubted that if it had not been for the fear of adding to the already enormous expense of the land required to be condemned, the Manhattan approach would have been carried at least to the Bowery, or, far better still, to Broadway? When this bridge is finished, according to present plans, it will be half useless, owing to the difficulties of access on the Manhattan side, and already suggestions have been made for a new thoroughfare to be cut diagonally across the city from this terminus to the vicinity of Cooper Union. The cost of such an avenue, if it were ever constructed, would be enormous. If a tunnel had been constructed instead of this bridge, it would have been completed long ago at a cost not exceeding one-third that of the bridge, and that tunnel would have terminated at Broadway, with possibly an intermediate station at the Bowery. Furthermore, it could have been continued at any time, at small cost, to the North river, if necessary.

The City is about to let a contract for the construction of the underground Rapid Transit Railroad. It is a mistake to think that this road will inure to the sole benefit of the Borough of Manhattan. It ought to benefit greatly also the inhabitants of the Borough of Brooklyn. But to do so to the best advantage it must be made accessible to them. Will any of the bridges built, building or proposed to be built over the East river serve as feeders to, or recipients of, the traffic on this road?

The old Brooklyn Bridge will so serve, but with the inconvenience of a change from an overhead to an underground system. The other bridges will be practically inaccessible.

If tunnels were to be built, however, the most direct connections could be made, and it would not be too much to expect

that in course of time passengers could ride without change of cars from the Harlem river to East New York or Coney Island.

It only remains to consider whether there would be any delay in the construction of tunnels from the necessity of securing additional legislation. Fortunately the Charter contains ample provision for this work. Section 48 provides that "the municipal assembly shall have power to provide, by ordinance, * * * for the building of bridges and the establishment of ferries over and of tunnels under any stream or waterway within or adjoining the limits of the city."

Section 415 vests in the Board of Public Improvements power to acquire title to lands above or under water required for tunnels or approaches thereto. Section 970 makes the general provisions of the city street opening law applicable as well to the procedure in acquiring land needed for tunnels, and by section 174 the awards, when made, are directed to be paid from the fund for Street and Park Openings.

In presenting these considerations to the Board of Estimate and Apportionment, I feel that the most momentous results will flow from the action to be taken by this Board. We are now at the turning of the ways, and, if the wrong path be chosen, an irretrievable damage will be done to the interests of this City and its inhabitants. It is my belief that if the City should persist in the folly of building enormously expensive bridges over the East river, which do not accomplish the purpose for which they are designed, the day will soon come when a correct solution, which is now possible, will become impossible.

The expenditure of $30,000,000, in addition to the cost of the Rapid Transit Road, will exhaust the City's debt-incurring capacity within constitutional limitations. If this $30,000,000

were to be spent in tunnels, about four times as many passengers could be carried as the two proposed bridges would accommodate; the tunnels would be ready for use long before the bridges; the people would be carried to and from the places where and whence they wanted to go, and not deposited in inaccessible localities, and the present congested condition of the principal thoroughfares of Brooklyn would be relieved. In all probability much less than $30,000,000 would accomplish this result.

But if, on the other hand, this $30,000,000—being the last dollars that the City now has to spend for any purpose—be largely wasted on two bridges which admittedly will not satisfy the demands of the people of Brooklyn, the Treasury will be exhausted and the City rendered helpless to afford any further improvement in transit facilities.

Never before, I believe, were public officers called upon to assume so weighty a responsibility; and to act according to our unbiased judgment, with the fullest information possibly obtainable, is a solemn duty. In the short time elapsed between the meeting of the Board of Public Improvements and this meeting there has been little opportunity for securing professional advice. I have requested, however, from two engineers of the highest standing, both of them specialists in tunnel construction, opinions on this subject. One is Mr. William B. Parsons, the Engineer of the Rapid Transit Railroad Commission, whose reputation needs no commentary; the other is Mr. John V. Davies, whose work in connection with the construction of the East River Gas tunnel renders his advice peculiarly authoritative. If replies can be obtained in time I shall ask the Board to give to these professional opinions the consideration they deserve.

The following resolution is also offered for the consideration of the Board.

Respectfully,

BIRD S. COLER,
Comptroller.

Resolved, That the Board of Public Improvements be requested, at the earliest possible date and within thirty days, to report in regard to the feasibility and desirability of accommodating traffic between the Borough of Manhattan and the boroughs of Brooklyn and Queens by means of tunnels under the East river rather than by bridges over said river, said report to cover, in addition to such other questions as may seem pertinent (1) comparative cost; (2) comparative time necessary to construct, and (3) comparative facilities for traffic; and

Resolved, That for the purpose of obtaining the greatest possible authority for said report, the Board of Public Improvements be requested to engage the services of the most eminent engineers familiar with the scientific problems involved in the scope of this inquiry, among whom the following are respectfully named for consideration:

Bridge Engineers—L. L. Buck, C. C. Martin, Samuel R. Probasco.

Tunnel Engineers—William B. Parsons, John V. Davies, A. Fteley.

I.

Expert Opinions in Favor of Tunnels.

New York, December 4, 1899.

Hon. Bird S. Coler,
Comptroller, City of New York:

Dear Sir—You advise us that the City of New York has under consideration the expenditure of some $28,000,000 for the purpose of building two bridges across the East river; one to the north and very near the present Brooklyn Bridge, and the other near East Sixtieth street, crossing over Blackwell's Island; and in response to your request we beg to report to you on some of the advantages of tunnels over bridges for dealing with the transportation problem of this city.

Manhattan forms the business centre of the Greater City of New York, and it is to and from it that the great tide of travel with The Bronx, Queens, Brooklyn and Richmond daily flows. The travel in Manhattan, north and south, is well cared for by the four lines of Elevated Railway and thirteen main lines of surface cars. Travel into The Bronx is covered by numerous bridges over the Harlem, by extensions of these elevated and surface lines, besides the service of the New York Central, Harlem, New Haven and N. Y. & Northern Steam Railroads. It is the great residential districts of Queens, Brooklyn and Richmond which are most inadequately provided for.

The Rapid Transit Commission is now letting contracts for construction of their great north and south subway, and it is to and with that line, as well as every existing line, that connection should be made to give the greatest efficiency. Apart from the ferries, the only existing thoroughfare over the East river is the overloaded Brooklyn Bridge; and now under construction the New East River Bridge for future service. The early growth of the cities placed the City Halls of New York and Brooklyn near the water-front, so that the Brooklyn

Bridge reaches nearly from one to the other. This cannot occur again. The New East River Bridge merely spans the river, with approaches long enough to enable the streets to be reached by practicable grade at each end. The same thing applies to the new bridges. They are connections from water-front to water-front, and travel must be diverted to come to them. For their construction enormously valuable real estate must be acquired, of which the cost is purely estimate. The trucking business is, for the most part, a river-front business, which will continue to be taken care of by the ferries, even though one of these bridges is to be built over the line of a ferry. The operation of the ferries is a source of revenue to the City. The light vehicle traffic is of little consequence, and might continue to cross the ferries, so that the provision of great roadway facilities on these bridges is not essential, and the earnings from wagon receipts will hardly pay the maintenance expenses. The river crossings are essentially passenger transportation problems. Four-track bridges are quite unnecessary, as the even distribution of traffic is better accomplished by multiplying the points of crossing rather than by the expenditure of huge sums on construction of a few great structures designed to concentrate travel. The cheapness of deep tunnel construction permits of doing this, and thereby subdividing the entries and promoting uniform expansion of the city and suburbs.

From the suburbs the travel is, of course, largest to the lower end of Manhattan, but it is enormous also to every part of the Island. It is obvious, then, that what is needed is to intersect every one of the 17 main north and south railway lines at numerous points by east and west lines, making through connection of the most rapid kind to the eastern side of East river. Tunnels are the only feasible solution of this problem. The capacity of a single double-track railroad should be the same whether tunnel or bridge, and the comfortable limit is about 15,000 passengers for the maximum hour, or, on the East river passenger movement, equivalent to 110,000 per day.

A double-track tunnel, to carry this number of passengers, can be constructed to do the same business as either of the two bridges proposed, from suitable terminal points on either side of the East river, and be fitted with efficient terminal stations and elevator service for $1,900,000 in place of the Blackwell's Island Bridge, estimated to cost some $13,000,000; and for $2,250,000 in place of the lower bridge, estimated to cost some $15,000,000. No real estate would be needed for the tunnel construction, as the City could use its own street property. For the amount proposed to be expended for the two bridges now under construction, no less than 12 double-track tunnels could be built from suitable terminal points near each shore, and it is obvious that such a multiplicity of connections would provide enormously greater facilities to the public than the concentration of travel to two bridges. All transportation facilities constructed by the City should be definitely part of a complete system. Bridges can only, possibly, be isolated units; and in their place should be constructed double-track tunnels, having their eastern portals at convenient collecting points, to take all the travel coming in the direction of Manhattan, and situated at intervals corresponding to the density of population and running in more or less parallel lines below the East river and clear across Manhattan Island, to intersect every north and south railway line; making "all-rail" connections to the proposed Rapid Transit Subway, and transfer connections with all surface lines. On the map herewith we lay down, arbitrarily, four such east and west lines, which would fairly and uniformly distribute the travel.*

1st. From West street, along and below Canal, Sullivan and Grand streets, to and below the East river to Kent avenue, and under that street to Flushing avenue, near Wallabout Market. This line would be 3½ miles long and cost $7,750,000; complete with stations.

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* See Map *post*.

2d. Crossing Fourteenth street, from the North river to and under the East river to and under North Ninth street, Brooklyn, with terminus at Union avenue, a total length of 3½ miles and cost $4,850,000.

3d. Crossing from west to east on Fifty-seventh street and under Blackwell's Island and streets of Long Island to a point of connection at Jackson avenue, with surface and Long Island Railroad lines. Distance, 3 miles; cost, $4,700,000.

4th. From Eleventh avenue, under Manhattan avenue and One Hundred and Twenty-fifth street, under the Harlem river and Randall's Island; Sunken Meadow and East river to Astoria, so as to connect with surface lines to be built on old Bowery road. Distance, 3½ miles; cost, $5,250,000.

These four lines would cost altogether $22,550,000. Each line is a complete railroad; while connected as it is with every north and south line, the service is incalculably greater in value to the community than two bridges at the water-front. The lower end of Manhattan is to be served by the proposed improvements of the Long Island Railroad; which, with its direct railroad connection, will be of the greatest possible advantage to the traveling public, and particularly so as it will form an "all-rail" through connection to all Long Island. It will be constructed by private enterprise, and has been designed to make a close connection with the future Rapid Transit Subway. South Brooklyn and Richmond must be served by an extension of the Rapid Transit Subway, and should be treated as part of that project. The crossing from the Battery to Brooklyn would be entirely in rock, involving cheap tunneling, and the line could be continued under Hamilton and Fourth avenues to Ninety-second street, crossing the Narrows to Vanderbilt on Staten Island, a distance of about 9 miles. This line of route is urgently needed and its value cannot be overestimated. These cross lines of tunnel, in conjunction with the Rapid Transit Subway, will comprise a complete system,

giving facilities to every section of Greater New York, and the Rapid Transit scheme, developed in this way, becomes a system for the entire city instead of what it has heretofore been, a project for Manhattan and Bronx only.

New York is peculiarly adapted for cheap and safe tunneling. Rock everywhere exists at very easy depth, and tunneling in rock is the cheapest class of the work. The entire bottom of East river is covered with hard, compact, glacial formations admirably adapted to safe and economical tunnel work. Tunnel construction to-day is an exact science, and costs can be very certainly estimated. Tunnel routes of railway can conform to irregular surface conditions in far greater degree than bridges. Grades can be carried up and down to effect connections, and directions changed to follow street lines, with no encroachment upon private property. This is particularly the case with deep tunnels built largely in the underlying rock. No damage is effected to abutting properties under modern methods of tunneling, and no claims for damage due to obstruction of surface rights are involved, as are almost invariably the case with bridge construction. In the river sections, a bridge must give clear height above tide of 135 feet, or height to grade line of nearly 150 feet, and under recent U. S. regulations this height must be carried to the pier line. A tunnel need only give 36 feet water depth below tide and safe depth for construction below that level, or, say, 60 feet to grade. These elevations involve approaches for tunnel of less than half the length of a bridge at same rate of grade. While the grade is adverse to traffic on a bridge, it assists acceleration in starting and braking in stopping a train in a tunnel, and so permits greater speed of train movement in tunnel than that across bridge. This high speed of movement is an essential feature of any transportation proposition for the suburban resident. Subaqueous tunneling is as easy and safe as under land. As an illustration: in the construction of the East River Gas Company Tunnel, we had at one time an open passage to the bed of the river, through which rubbish came, and yet it caused

no serious inconvenience or delay in the progress of the work.

There is no necessity, therefore, to cross the river by the shortest route, as is usually adopted by any bridge crossing, but a tunnel may take any direction advantageous to terminal connections.

With deep tunneling no interference with the surface is occasioned during construction, nor disturbance of sewers, pipes or electric subways. In tunnel construction labor is the greatest item and the number of men employed is very great. Bridge construction, on the contrary, is, for the most part, executed in another State, and the labor employed on foundation construction and erection is a very small item of the whole cost. Thus in tunnel construction the greater part of the money expended is retained within the city itself, while bridge construction enriches other communities. In the operation of completed line, the cost of maintenance of tunnel structure is practically nothing, while the single item of "painting" a bridge structure is of serious consequence. The depreciation of a bridge is far in excess of that of a tunnel.

The operation of a tunnel railway is not interfered with by climatic conditions of fog, snow, ice, etc., as is a bridge.

For short spans and low elevations, bridges are the cheaper in first cost, but when the necessary span is great and pier height large, then the first cost and maintenance of a tunnel is enormously less than that of a bridge for conducting railway transportation.

A tunnel crossing below a navigable waterway leaves the water-front unbroken and navigation unimpeded, which a bridge does not do, and the frontage occupied by the piers is permanently lost to the City for dock rental. A street or public place may have a tunnel in regular operation below, while its use is unimpaired on the surface. Any bridge structure reduces the value, if it does not destroy the surface.

Tunnel construction may be as rapid as is desired, depending only on the number of faces worked. Complete tunnel can readily be built from two faces at the rate of 3,500 feet

per annum, so that the rate of progress is very much greater than is usual with long span bridge construction; with electric traction the question of ventilation and freshness of atmosphere in tunnels is absolutely solved. No comparison should or can be made with any tunnel in which coal-burning locomotives or horses are used. The newly constructed deep tunnels of London are magnificent demonstrations of this fact.

For real rapid transit between all districts of the five boroughs of our city, the development of the complete system of tunnels above outlined will effect the most complete and perfect results and induce the most uniform expansion of the city as a whole.

Respectfully submitted,

JACOBS & DAVIES.

4TH DECEMBER, 1899.

The Honorable BIRD S. COLER,
Comptroller:

SIR—In response to your inquiry as to the relative advantages of bridges or tunnels connecting Manhattan and Brooklyn I beg leave to state that a tunnel possesses the following advantages over a bridge:

1. Economy in cost of construction.

2. Great economy in cost of annual maintenance.

3. The tunnel requires no purchase of expensive land for approaches, as it can utilize for this purpose City property beneath the streets. This is a saving not only in prime cost, but avoids the withdrawal of valuable real estate from taxable values.

4. A tunnel not requiring costly purchase of real estate can be run anywhere, even directly across the city, and so connect with every north and south transportation line in Manhattan.

5. The gradients on the approaches are descending from the terminal points in the case of a tunnel, and ascending in the case of a bridge. Trains can therefore be started more quickly and operated more economically in the former case.

In constructing tunnels beneath the East river there is nothing experimental in the project. The soil beneath the river has been tested by boring at a number of points, and it is known to be an admirable material through which to bore. Beneath the Battery and South Brooklyn the bottom is rock; north of that, at such depths as a tunnel would probably be constructed, it is a more compact material, which, with modern methods, is easily penetrated and without any uncertainty.

A modern tunnel for such a purpose is a tube composed of heavy cast-iron plates, bolted together and absolutely watertight. On the outside of the iron there is a layer of concrete to protect the same from the action of water, and the inside can be lined with light colored or enameled bricks, or at least of such color or design as to give the most pleasing and attractive appearance.

Tunnels of this character have been constructed in so many places abroad as to place their stability beyond question. In London there are constructed, or under construction, twenty miles of double-track tunnel of this form, at depths ranging from 50 to 100 feet beneath the surface of the street. There are two double-track tunnels beneath the Thames, and the large Blackwell tunnel under the Thames, below London, a tube 27 feet in diameter, containing a roadway for vehicles and sidewalks for pedestrians, with a length of over 6,000 feet, of which about 1,200 feet are beneath the river proper.

In Glasgow, beneath the Clyde, there are two double-track tunnels passing under the river twice, together with a triple-tube tunnel constructed by the City authorities, with a length of 750 feet. Two of the tubes are used by vehicles and one by pedestrians.

There is also a similar tunnel now existing beneath the East river, passing under Blackwell's Island. This tunnel, although constructed for gas purposes, is large enough to pass a surface railway car, and can be inspected at any time.

The two bridges contemplated between Manhattan and Brooklyn are estimated to cost $28,000,000, exclusive of interest during construction. Two double-track railroad tunnels on the same location would cost, approximately, $8,000,000; or, by extending the Blackwell's Island location from Second avenue to Third or Fourth avenue, where the traffic facilities are much better, the cost for this tunnel would be, approximately, $4,000,000, as against $12,500,000 for the bridge. In like manner, by extending the Pike's Slip location from its proposed terminus at Canal street to the location of the underground railway at Elm street, the cost of such a double-track tunnel would be, approximately, $6,000,000, as against $16,000,000 for the bridge. Or, for the same amount, namely, $28,000,000, as the two bridges are to cost, eight double-track tunnels of equal length could be constructed, or, say, six or seven double-track tunnels not only to the east side of the city but reaching across to the Rapid Transit Railway or to the

other transportation lines—that is to say, for the same expenditure on the part of the City, not only could communication be secured on the two locations as suggested, but additional means of communication could be secured at South Ferry, Wall street, Twenty-third, Thirty-fourth and Forty-second streets.

The advantages of the multiplicity of connection are so obvious as to not require elaboration—in giving greater convenience to the people by providing connections with all the north and south lines on Manhattan, without necessitating any intermediate transfers, and so expediting the inter-urban journey, and distributing the travel, and so avoiding the growing tendency to congestion. These advantages are worth securing, even at a greatly increased cost; but when they can be secured at the same price, or even less, the advisability of considering tunnel construction is obvious.

In conclusion, I desire to call your attention to the desirability of tunnel construction in connection with the proposed Rapid Transit System. I understand there is a great desire on all sides to connect the Battery in Manhattan with South Brooklyn, and that the idea of a bridge has been abandoned by the City authorities, with much regret, as being impracticable.

The bed of the river at this point being rock, there exist the very best conditions for tunneling. A double-track tunnel can be constructed from South Ferry to the foot of, say, Atlantic avenue, in South Brooklyn, at a cost of $3,000,000, in round numbers, and by connecting such a tunnel with the Rapid Transit Railway now about to be undertaken, and which, when built, will be the City's property, the South Brooklyn population would not only be in direct connection with the Borough of Manhattan at least as well as by a bridge, but in immediate physical connection with the Rapid Transit System. By running through cars passengers can be taken directly from Brooklyn on express trains of the Rapid Transit System to any point in the boroughs of Manhattan and Bronx. Such a tunnel can be either extended to such a point or points in Brooklyn as may be desired, or connection can be made with its terminus

by the existing surface lines, and so affording means of local distribution.

By using electricity or compressed air for the motive power, and by lighting the tunnel by electricity, the existing prejudice to tunnels based on the ordinary smoke-laden and dark, damp structures, will be at once destroyed. Under such conditions the atmosphere will be found to be, on the average, more desirable and agreeable than on a bridge, as the tunnel will be free from the effects of storms, blizzards, rains and hot sun.

Respectfully yours,

(Sgd.) Wm. Barclay Parsons.

II.

Expert Opinions in Favor of Bridges.

1. The two methods of crossing rivers by means of tunnels and bridges have been very thoroughly considered by engineers under many varying conditions; with the net result in the verdict that where a bridge is possible it is preferable, and only where a bridge is practically impossible is a tunnel to be properly considered.

There have been exceptions to this general proposition, and such exceptions are invariably conspicuous proofs of the general proposition.

The sub-aqueous tunnels of London are damp, dark and offensive, almost without exception, and no one capable of forming an unbiased opinion would prefer them to bridges as a means of crossing a river.

The short sub-aqueous tunnels of Chicago have been condemned almost without exception. Some have been abandoned and replaced by bridges, and it is doubtful if any one can now be found who would advocate extension of their use in that quarter.

In Great Britain, where experience with sub-aqueous tunnels have been more extensive than in any other country, despite the stupendous spans and enormous cost of securing a double-track railroad bridge across the Firth of Forth, a tunnel was not even considered subsequent to 1807 when long span bridges were scarcely thought of. Subsequent development of structural steel completely killed the tunnel project.

2. Sub-aqueous tunnels such as would be required for city traffic under the East river would be purely experimental, both as to execution of the work and operation. The construction of one such tunnel under the North river was tried and abandoned after the expenditure of large sums of money.

The great depth to which it is necessary to go, the uncertainty of the material that is necessary to penetrate, the utter impossibility of even approximating the cost of such work,

makes it an engineering problem, to say the least, doubtful of economical solution. Then, if it is accomplished, the meagreness of the results, the great difficulty of maintenance and the serious objections and dangers attending the use of it, are cogent facts against a tunnel.

3. It would be almost impossible to so construct such a tunnel as to render it dry or to avoid the necessity of a complete system of drainage and an extensive pumping plant to remove the inflowing water, both seepage and rain from the open cuts.

4. It is practically impossible to locate a tunnel under the East river, having a grade that would permit team traffic and at the same time have a terminal at a reasonably accessible point on the Island of Manhattan. A tunnel would have to be at a depth of not less than 120 feet below mean high water at the centre of the river, and would have to come to grade at 30 feet above mean high water. To accomplish this would require an approach of about 4,000 feet length, a feature not easy to obtain. It would be well to have produced some general plans showing depths, grades, locations, etc., of any proposed tunnel. It is not venturing very far to assume that no such design can be found adaptable for general city usage, or, in other words, be made to fill the functions of a bridge.

The proposition presented so far is too general and the claims too vague to enable any specific refutation of them to be made.

5. Assuming the section of a tunnel to be circular, as it would probably have to be in a case like this, a tunnel about 28 feet in diameter would be required to accommodate a double-tracked road, either for trolley cars or trains similar to elevated trains. For full-sized railroad trains a larger section would be required.

Now, to furnish the four trolley tracks, two elevated tracks, two roadways, two sidewalks and a bicycle path, which is to be the capacity of the new East River Bridge, would require at least five of these 28-foot tunnels, or else six 15-foot tunnels

and two 28-foot tunnels, which latter arrangement would be cheaper. The only fair basis of comparison of the two systems is that of capacity furnished. To speak of substituting a tunnel for a bridge, without qualification or comparison of a capacity of each, would be an absurdity. Further on this basis it can unquestionably be shown that the cost of a system of tunnels would vastly exceed the cost of a bridge of the same capacity.

6. Tunnels are wholly unfit for the use of teams and pedestrians, and, in fact, only tolerable when of any considerable length for the use of fast trains. Even in this case, although tolerable when unavoidable, they are wholly undesirable, as can be readily demonstrated by a trip through the Park avenue subway, especially in hot weather. And here the conditions are infinitely more conducive to comfort than in a sub-aqueous tunnel, whose means of ventilation can only be had by the use of machines. The Boston subways are often cited as conspicuous examples of the excellence and inoffensiveness of tunnels. Subways are not tunnels, for in almost all cases these are above water and are easy to keep dry and clean as well as properly ventilated. Further, they are near enough the surface to be readily accessible. In fact these subways are nothing more than covered trenches, not tunnels at all.

8. There seems to be but one possible advantage in a tunnel under the East river, and that would be in furnishing to the railroads of Long Island access to New York. It would be practically inaccessible and useless for traffic of all other kinds, and it can be counted as absolutely assured that all pedestrians, trucks and vehicles of all kinds would continue to use the ferries rather than resort to a subterranean passage with all of its discomforts, difficulties and dangers.

When an entrance to New York across the East river was contemplated and work even begun to accomplish this object, a bridge and not a tunnel was the means adopted, doubtless after mature consideration of both systems.

R. S. Buck.

A tunnel, to give accommodation equal to the New East River Bridge, would have to provide for six railroad tracks, two wide carriageways and a promenade for pedestrians—equivalent to eight tunnels:

One for each railroad track	6
Two for double carriageways and pedestrians	2
Total tunnels to equal one bridge	8

The terminals in Brooklyn would probably be at grade. If these tunnels were placed side by side, with sufficient earth between them to insure proper support of the overlying material, they would occupy a space of about 300 feet in width. This would not only entail an additional expense for tunnels, but would require an enormous expenditure for approaches to the tunnels. In the case of the elevated railroads, not only would the elevated tracks need to be brought to the ground, but large amounts of property would need to be purchased on which to locate the curves necessary to reach the mouths of the various tunnels.

In New York the tunnels could not come to the surface on account of the grade, and the terminal station would be over 100 feet below the street, and all of the traffic would have to be hoisted to the surface by elevators; to obtain room for these would necessitate the widening out of the terminal until it would occupy a very large area. Then, if it were possible, it would be well to imagine the utter confusion of an attempt to elevate 20,000 people an hour—that is, a 5-car trainload every minute, and the elevating of 300 vehicles per hour, or 5 per minute—equivalent to a steady stream of trucks such as passes over the present bridge nights and mornings. Also the elevating of crowds of foot passengers (that is, if they could be induced to go down into a tunnel). To accommodate all of this traffic at the tops of the elevators at the surface of the ground, would require an enormous area, as space would neces-

sarily be provided for discharging all of these different elevators for car passengers, foot passengers and teams, and provision made for the quick dispersion of these loads. At the same time, approaches to the tunnels would have to be provided for teams and people going in opposite directions.

When account is taken of the numerous tunnels required to be built and the additional land required for approaches, it will readily be seen that instead of a tunnel of equal capacity as a bridge, costing less than a bridge, it will be greatly in excess; and when the inconvenience, crowding and annoyance incident to underground transit are considered, there remains no longer any question as to the comparative cost of tunnels and bridges, nor their convenience. All is in favor of bridges.

C. C. Martin,

Chief Engineer and Supt.

It is difficult to make any comparison between tunnels and bridges; the first are seldom used, except as a necessity, while bridges have been in constant and increasing use, for ornament as well as necessity. As a means of crossing a navigable stream much used for water traffic, and passing through a great city, tunnels are seldom used, except where bridges cannot be built. Even on the River Thames, where tunnels can readily be excavated on account of the underlying clays, bridges are still constructed at great cost, so much more are they appreciated by the public who use them. Most tunnels are dark, and if constructed below the bed of a river, both damp and dark. If the river is deep, the tunnel is equally so, and the approaches have to be very long if high land occurs on either side of the river, which increases the length of the approach as well—or if not increased in length, they must be made more steep.

At the lower end of Manhattan Island, and below the Suspension Bridge, the depths of water are from 30 to 50 feet; above the bridge from 50 to 70 feet, and between Blackwell's Island and Manhattan the water is from 40 to 112 feet deep. These depths necessitate long approaches, throwing the ends far back from the water-front. This is equally true of high bridges, but no one objects to the length of a bridge, or its height, as fixed by the War Department, which furnishes fresh air, a beautiful view, and, above all, the light of day or the illumination at night, as contrasted with the passage through a tunnel, no matter how well lighted, which is damp, either with seepage or condensation, and under the bed of a river, and from which only egress can be made by means of a steep slope or an elevator; beside, there is no comparison between the facilities which a bridge affords for the passage of loaded or unloaded vehicles; to these or to persons traveling in their own vehicles, the tunnel can afford no attraction whatever. A tunnel sufficiently wide to accommodate the travel on the East

River Bridge now in use should have at least a clear headroom of 20 feet, so that in 40 feet of water and having 3 feet of thickness of crown below the level of the bottom, and allowing only, say, 10 feet of the bottom above the roof, it would be 73 feet from high water to the floor. Apart from this depth of the interior of the tunnel is to be added the height of the land above high water. The drainage of the tunnel cannot be neglected; all the water that falls on the land cuts, connecting with the tunnel, has to be pumped out, involving the continuous use of pumping machinery. If springs are met in the course of construction, this water has to be taken care of as well; and as it has been shown at various times that it is dangerous to suppress springs, more machinery has to be supplied. In the case of the tunnel underneath the Severn on the Great Western Railway, continuous pumping is requisite and the total minimum quantity of water raised in twenty-four hours is 27,000,000 of gallons, and the power provided is equal to raising 66,000,000 of gallons. The " Mersey " tunnel has a minimum thickness of rock of 30 feet over the crown, and pumping machinery is provided for raising 27,000,000 of gallons per day—half of which quantity is about the present inflow. For ventilation of the Mersey tunnel—which is also needed in every sub-aqueous tunnel—fans of 30 and 40 feet diameter are employed. For a railway passage, a tunnel may be as efficacious as a bridge, but for general public use there can be no comparison. Take, for instance, the crossing from Queens to Manhattan, the elevation of ground on the Queens side is 12 feet above high water, and on the Manhattan side from 50 to 70 feet. The tunnel on the Queens side could be constructed as far as the edge of the East river without much trouble through the alluvial soil, but from there on and across the Island the grade would have to fall to a bottom level of 34 feet of water, and in the western channel as great a depth as 96 feet of water would be met. This would make the tunnel below the grade of the proposed bridge at its western end about 157 feet, without speaking of the depth over the crown of the

tunnel of the clear headroom necessary between the roof and the floor. A lower level for the outlet of the tunnel would have to be sought by increasing the length of the tunnel. Vertical lifts would have to be used to bring passengers to the surface, as well as vehicles—unless sufficient room could be found for slopes, a great portion of which would have to be constructed underground.

It is not believed that a tunnel or tunnels of any description will accomplish the work of a bridge having two 16-foot carriageways, an independent promenade for foot passengers, 16 feet wide, with room for four trolley car tracks and two elevated railroad tracks, covering in all about 105 feet of horizontal space. To do this with tunnels it would involve the use of six tunnels 16 feet clear width and two tunnels 20 feet wide, provided at a much greater cost and giving much less comfort to those who use them.

SAML. R. PROBASCO,

Chief Engineer.

III.

Replies in Favor of Tunnels.

DECEMBER 9, 1899.

Hon. BIRD S. COLER,
Comptroller,
City of New York:

SIR—We have read with much interest the statement of the case for East river bridges, as presented by Messrs. Probasco, Martin and Buck.

These three statements present the advantages of the magnificent bridges proposed. Each draws its comparisons between a structure which, we do not deny, will remain to posterity as a monument to its builders; and a tunnel, of which neither writer appears in the least degree to be posted as to modern construction, conditions or operation. We do not question the value of a bridge over the East river, nor do we take any exception to the work which these gentlemen have designed, but we maintain emphatically that the bridges planned are not the most economical nor the most advantageous means of providing for the needs of the people on either side of the East river.

We do not suppose that these bridges are being designed simply as "things of beauty," but that the need of conveniently transporting the traveling public, efficiently and rapidly, is the prime cause of their construction.

No bridge, tunnel or other route of travel will ever again be built within the corporate limits of this city which will require or be permitted to concentrate and congest traffic, as is the case with the present Brooklyn Bridge. There is plenty of latitude yet left to increase the transportation capacity of that thoroughfare. On heavy travel days on the Brooklyn Bridge there are transported in the two lines of cars operated by the Bridge and the Brooklyn Rapid Transit Company as many as 400,000 people; yet the average week day travel does not exceed about 300,000 passengers in both directions. The

whole object of new bridges is to relieve this crowded condition, to draw off from the existing route some portion of its load, and to create new routes of travel. What value, then, is it to multiply tracks on one bridge, by putting in six tracks for cars. As a matter of fact, these gentlemen make a huge "virtue of necessity." They find in their strain calculations that an enormous width is absolutely necessary to provide for lateral stresses due to wind pressure and vibration on these very great spans, and that it is perfectly easy to put in a number of extra tracks, which look and sound well, without adding very much to the initial costs. They very rightly put them in, and work backward from the number of tracks to calculate the needs of the public, instead of the rational method of calculating from the needs of the public what provision should be made for handling them.

The travel capacity of a railroad for transportation use is controlled entirely by its capacity in the busiest hour. With crowding into cars and making people stand (Bridge fashion), as many as 20,000 passengers per hour may be conveyed, but in legitimate manner no more than 15,000 passengers should be handled in one hour. This is, as we before stated, equivalent to 110,000 per day. It is a well-known fact that about 9 per cent. of the population of the city cross the East river daily, and therefore this travel capacity for a single double track will accommodate a population tributary to any bridge of 1,220,000 persons. On each of these proposed bridges, then, accommodation is to be provided for tributary population of more than the entire 1899 population of the whole of Greater New York.

This is not reasonable. A single double track railroad is ample provision for the traveling public at any one point. One of these new bridges is almost to parallel the existing Brooklyn Bridge, and its especial function will be to relieve its burden, which is very right, but we hardly believe it will do so to any great extent. The other bridge, crossing Blackwell's Island, is to extend from a point on Second avenue to an entirely

unsettled and slightly improved portion of Long Island City. We do not deny that the construction of the bridge will induce the building up of that portion of Queens, but we do deny the necessity now or within the next fifty years for six tracks of railroad.

Neither bridge project provides in the remotest degree for South Brooklyn, for Hunter's Point or Greenpoint. The statements for the bridges take out of the case the existence of the ferries, which are a source of great revenue to the City. As we before stated, the bulk of the trucking business of the city is a river front business. The building of the Brooklyn Bridge has not stopped the trucking over Fulton and Catharine Ferries. No heavy truck would go to a bridge approach, to pull up a long grade, between 3 and 5 per cent., when they can advantageously take a ferry. The provisions of handsome roadways on these bridges is simply incidental to their construction, and in no sort of respect a reason for building them. Their construction will not save the vehicle any money, and at the worst case not over ten minutes actual time. If roadways in addition to those on Brooklyn and East river bridges are absolutely necessary, they can economically be constructed in tunnel. The City of Glasgow did this under the Clyde with entire success, and the recently opened Blackwall Tunnel, under the Thames (which is purely a highway for wagons and pedestrians, having open approaches with elevator service for wagons and passengers at other points), has evidently not been examined by either of these gentlemen, or they would not describe it as either damp, dark or objectionable. The Chicago tunnels at Lasalle and Clark streets have been entirely taken possession of by the trolleys, and there is no pretense, apparently, to keep them clean or to watch them, and they are built so near the bed of the river that it is usual for vessels to lie aground on top of them. These gentlemen have apparently not followed in any way modern methods of tunneling, or some of the statements would not have been made as to grades, depths, dampness, and

so forth. The Hudson river tunnel cited is now empty, and the seepage in 4,000 feet of subaqueous tunnel is not sufficient to fill a ½-inch diameter pipe. The statement as to the Severn tunnel was correct, while it was under construction, at which time the writers were familiar with the works. At that time there were six pumps running. The tunnel was in limestone rock, and the subterranean channel for the entire water supply for ten miles' radius was tapped and flowed into the tunnel. This was under land and not under water. On completion of the work part of these pumps were taken away, and only one pump is used to handle the influx. Any person who has examined or traveled in the new electrically equipped London tunnels will not uphold the statements made concerning them.

The question of elevator service is a perfectly simple proposition, and would readily be met by either of the half dozen elevator builders of America to-day. One of the latest of the London deep tunnels, the City and Waterloo Railroad, has demonstrated what can be accomplished in this direction. This line, with its terminal station in the city, is in daily operation (to the complete satisfaction of passengers) underneath the street, in the square in front of the Bank of England and Royal Exchange. No real estate is used. The entire square is roofed over to form the surface of the street. Below is an enormous open area, forming a promenade or plaza, with stairways on the corners of the sidewalks of the five intersecting streets. In the centre of this plaza are the ticket booths, railings and elevators to the deep tunnels of the City and Waterloo Railway. If London can do this, why not New York also? This terminal is at a location more busy than any single spot in New York. It is the very heart and centre of London's business. The City and Waterloo Railway pours all the passengers from the Southwestern Railway and from the Surrey side of the Thames, under that river, into the business heart of the city. Its traffic is far in excess of any which will accrue, for many years to come, to any one of the new bridges. The work of construction was carried on to completion without for

a day interrupting traffic on that square. This railroad passes below the Thames with no more cover between the roof of the tunnel and the water in the river, in places, than five feet. No person who has examined this work will call it damp or ill ventilated. We do not propose to quibble over the details of this proposition. Bridges have their field and rightly and properly so. The present case is not one for sentiment; it is the broad question of rapid and efficient facilities for transportation between our boroughs. We hold that no thoroughfare is needed in any one location of the magnitude of these bridges. That the construction of additional bridges for vehicular traffic is not necessary, and that the City is not warranted in expending any huge sum of money for that purpose, or to provide for bicycles except as incidental to the passenger transportation problem. That one double track railway for street service is all that is demanded or desirable for any single locality, and that these should be multiplied in as many localities as possible, so as to distribute business and build up the city more uniformly, increasing the property values by so doing.

The only economical manner of meeting this case is by tunnels intersecting all possible avenues of traffic on both sides of the river, and not by use of a single terminal station on either end.

There is far more urgent need for communication between lower Manhattan and South Brooklyn than for either of the bridges planned. The Bridge Department has acknowledged that the situation is not a feasible one for a bridge. It is eminently practicable for tunneling. The statements adverse to tunnels seem to be purposely misleading in certain respects. We no longer figure upon out-of-date methods of construction, any more than the bridge engineer considers any other material than steel for bridge construction. We no longer propose to use coal-burning steam locomotive engines as our motive power, and consequently we do not require rotary fans for drawing off that sulphurous smoke. The costs of construction

can be certainly and exactly calculated, and in every way as closely, and usually more so, than the estimates for long-span bridges. These loose statements on either side are irrelevant. The one point to keep in view is to produce the greatest benefit to the greatest number, at the least outlay; and in the particular case of the East river transportation problem, the case can be proved in favor of many tunnels, and their efficiency demonstrated from the parallel case of recent developments in the one city greater in size than our greater City of New York.

Yours respectfully,

JACOBS & DAVIES.

New York, 9th December, 1899.

The Hon. Bird S. Coler,
Comptroller,
City of New York:

Sir—I have read the reports of Messrs. Probasco, Buck and Martin that you have sent me.

The one argument in common which they all advance is that of the number of tunnels (eight in number) required to do the work of one bridge. Taking the new East River Bridge as a type, that may be so; and the fact that it is so is one of the principal reasons for avoiding bridges. If, by some convulsion of nature, the East river should be filled up, and the two boroughs of Manhattan and Brooklyn should thereby find themselves separated by a strip of land, would the City authorities permit the erection of impassable barriers extending for a mile, and then at such intervals lay out very wide streets filled with a number of railroad tracks and carriageways, or would they simply extend each street, comparatively narrower, and, consequently, with a less carrying capacity than the bigger thoroughfare, and so make each street connect with the one opposite in the other borough? The answer to this question is obvious.

The bridge has, of necessity, very expensive land terminals and foundations which are substantially independent of the cost of the structure. It is, therefore, economical to build a bridge as large as possible, involving, in practice, a congestion of travel at both ends. Tunnels, on the other hand, are comparatively small, and need not be built more in number than two at a place. The eight tunnels required to compensate for the new East River Bridge could, therefore, be built two each in four different places, and serve thereby to distribute the traffic much more evenly and conveniently and according to the rational method which would be adopted if the river did not exist. It is this one feature which alone makes the tunnel plan better than that of the bridge.

Of specific objections beyond this one point in common Mr. Martin urges none. Messrs. Buck and Probasco have submitted several, but which—all without exception—go to show that they have in their own minds the picture of an old-fashioned, leaky, damp, disagreeable masonry structure.

Such are the Severn, the Mersey and the London underground in England; the Fourth Avenue tunnel in New York, and the Chicago River tunnels, Chicago—all of which, except the last, are given over to the use of soft coal-burning locomotives at frequent intervals. Such structures, used as they are, are merely examples of "what not to do," and are according to a design that no intelligent engineer would duplicate to-day.

The modern tunnel is a metal-cased, absolutely water-tight structure, lined with enameled bricks, and therefore clean and sightly, and, with electricity or compressed air as the motive power, possesses an atmosphere which will, all things considered, average better than that on a high bridge.

Mr. Buck states that a tunnel beneath the East river would be experimental in character, and with a cost not susceptible of determination. His time has been so completely taken up in his excellent work for the great bridges across the East river that it has escaped his attention that a tunnel already exists under the East river which cost considerably less than $500,000. There is nothing, therefore, experimental in the idea, and the cost of such construction can be foretold and contracted for as readily as the foundations of his own bridge.

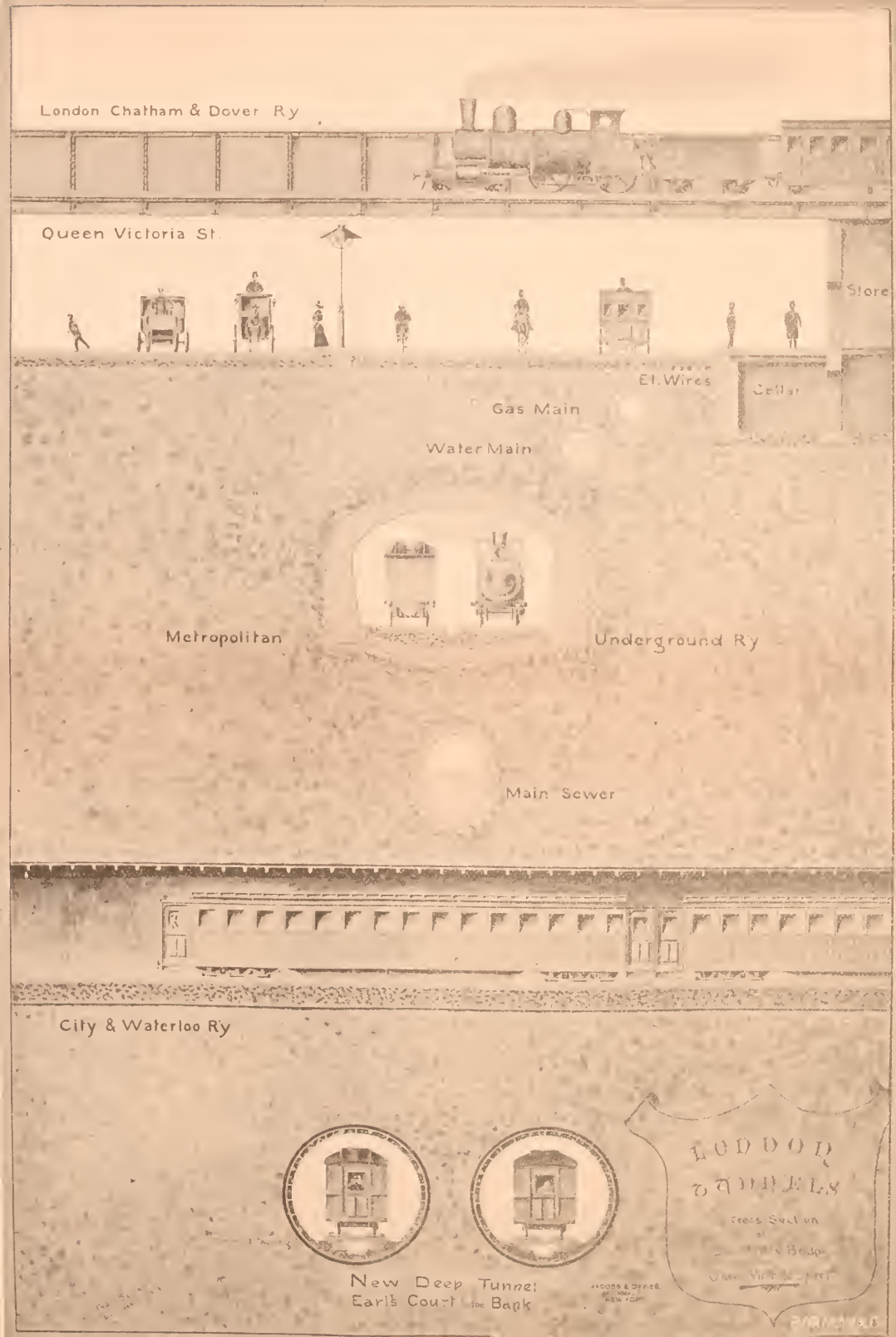
Messrs. Buck and Probasco argue as to the relative advantages of bridge and tunnel profiles. To simply state my own opinion in contradiction, which I do, is not argument. Such difference of opinion indicates very clearly the necessity for comparative study and report, as you have advised. If this whole subject were so studied, it would be seen, I am confident, that tunnels would possess more favorable gradients and give greater convenience to the people than the proposed bridges.

Respectfully yours,

Wm. Barclay Parsons.

The East River Gas Tunnel.

Cross Section showing Tunnels at Blackfriars Bridge and Queen Victoria Street, London.


London Chatham & Dover Ry
Queen Victoria St
Store
Et. Wires
Cellar
Gas Main
Water Main
Metropolitan
Underground Ry
Main Sewer
City & Waterloo Ry
New Deep Tunnel
Earls Court
the Bank
LONDON
TUNNELS

Map showing Locations of Bridges and Proposed Tunnels.

AVERY CLASSICS

Explanatory Remarks -

Bridges built and under construction shown thus ———

Bridges proposed " " .....

Tunnels proposed " " - - - - -

Long Island Rail Road Tunnel proposed shown thus -.-.-.-

Rail Roads & Elevated Roads shown thus ———